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DEVELOPMENT OF A
KINESCOPE QUALITY MEASURING DEVICE

A THESIS

By

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DEVELOPMENT OF A

KINESCOPE QUALITY MEASURING DEVICE

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I. INTRODUCTION

There are many sources of distortion in a television picture --- the camera tube, camera control circuits, the transmitter, the receiver, and the kinescope all contribute distortions of various kinds. This paper is concerned with distortions from only one source, the kinescope and its associated deflection and focussing circuits, whether they be electrostatic or magnetic. The kinds of distortion from this source are discussed, and then the means of detecting and measuring them that have been used are described. The remainder, and majority, of the paper is devoted to the detailed description of a "Kinescope Quality Measuring Device" and the problems encountered in building it. The Kinescope Quality Measuring Device is a convenient means of observing and measuring the distortions of a television picture contributed by the kinescope and its associated deflection and focussing circuits.

II. TYPES OF DISTORTION

There are four major kinds of distortion in a television picture which are caused by imperfections in the receiver kinescope and its associated deflection and focussing circuits:

a. Non-linear horizontal sweep.
b. Non-linear vertical sweep.
c. Deflection defocussing.
d. Barrel and pincushion distortion.

1. Non-linear Sweeps

It is assumed that the scanning beam of the camera tube is deflected horizontally and vertically through equal increments of distance in equal increments of time. When these conditions are satisfied, it is said that the camera tube has "linear" horizontal and vertical sweeps. The kinescope, then, must also have linear horizontal and vertical sweeps. Picture elements would otherwise be displaced from their proper location in the scene being televised. A man's face for example, could be compressed or stretched in either the vertical direction or the horizontal direction. In practice, perfect linearity of sweeps is not attained because of the difficulty of generating perfect sawtooth voltage and current waveforms and uniform fields. The degree of linearity is expressed as a percentage:

Percent non-linearity =

$$100 \times \frac{\text{The distance from its proper location of that picture element having maximum displacement}}{\text{Length of sweep}}$$

2. Deflection Defocussing.

It is relatively simple to focus all the electrons of the scanning beam into a small circular point at the center of the kinescope with no deflection voltages applied. When the beam is deflected, however, there are a number of things which cause the spot to change size and shape as it moves over the face of the kinescope. This is called deflection defocussing. A short discussion of each of its causes follows.

a. The cross-section of the beam is not constant in size and shape along its length, so unless all points on the face of the kinescope are equidistant from the center of the focussing elements, the face will intersect the beam at different points along its length and the shape and size of the spot will change as it moves. All points would be equidistant from the center of the focussing elements if the kinescope face were spherical. It is preferable to make it spherical from the structural point of view because an evacuated spher-

ical container withstands greater pressure than any-other shape of container. But a flat scene reproduced on a spherical surface appears distorted because of foreshortening. This is undesirable, so manufacturers strive to make the face of the kinescope flat. Defocussing effects are minimized by making the scanning beam cross section as constant as possible along its length in the vicinity of the kinescope face. Even if this were perfectly done, though, the spot would still change size and shape because the beam strikes the flat face of the kinescope at varying angles as it is deflected.

b. It is difficult to produce uniform magnetic and electrostatic fields for deflecting the scanning beam. Around the plates used to create an electrostatic field, there is always fringing. The effect of fringing is to place a cylindrical lens in the path of the scanning beam. The lens changes the size and shape of the spot as deflection changes. Non-uniformity of the electrostatic field is minimized by properly shaping and positioning deflection plates. Something similar to fringing exists in a magnetic field. The form of the La Place equations for a magnetic field in free space shows that it is impossible to obtain a uniform magnetic field.

The scanning beam has a finite cross-section, and as it passes through a non-linear magnetic field, the electrons in one portion experience a different force than electrons in another portion. An elliptically shaped beam results.

c. Electrons are emitted from the cathode at various velocities. The amount of deflection of electrons varies with their velocity. In a magnetic deflection system, deflection is inversely proportional to electron velocity. In an electrostatic deflection system, deflection is inversely proportional to the square of electron velocity. Since there can be no control over random electron emission velocities, a magnetic deflection system minimizes defocussing due to this source.

3. Barrel and Pincushion Distortion

This type of distortion is produced by a magnetic deflection system, arising from a non-uniform magnetic field. If the magnetic field producing horizontal deflection is barrel-shaped, as in Figure 1a, "pincushion" distortion results, as in Figure 1b. If it is pincushion-shaped as in Figure 1c, "barrel" distortion as in Figure 1d results. These distortions are due to the fact that

electrons are deflected the greatest distance where the density of magnetic flux is heaviest. If the deflection coils are wound so that the current density along their peripheries varies as the cosine of the angle measured from the edge of the coil, barrel and pincushion distortion are minimized.[1]

All of these distortions can be reduced so that in a television receiver they are not offensive to the eye. To develop the circuits which minimized distortions required test instruments which made it convenient to detect and measure the distortions. Several such instruments have been developed and are in use. They will become more essential in the future, for as competition in commercial television becomes more intense, distortionless pictures will be a good selling point and a laboratory aim. Moreover, many television applications recently conceived cannot be made until better linearity, resolution, and circuit stability are achieved. For example, the Navy finds that it would be desirable to transmit a television picture of meter boards in a ship's engine room. These boards are long, contain many meters with fine scales and needles. Better linearity, and probably better resolution, are essential

1. A. G. Jensen, "Film Scanner for Use in Television Transmission Tests", Proceedings of the I. R. E., Vol. 29, Page 243; May, 1941.

if accurate meter readings are to be read from a television picture much smaller than the board itself. The Navy also feels that it may someday be necessary to obtain a television presentation of the entire horizon and the sky overhead. The matching of pictures from the number of cameras that would be concerned here would require almost perfect linearity, and the detection of small targets in the sky will necessitate excellent focussing as well as better resolution than now exists. In both these applications, unmonitored operation is desired. In other words, the circuits must maintain constant linearity and focus once adjusted, and at present this is impossible. With all this work facing engineers, it is essential that simple, rapid means of detecting and measuring distortion be provided them.

III-METHODS OF MEASURING KINESCOPE DISTORTION

In order to detect and quantitatively measure these distortions, simple devices have been used. Deflection defocussing is searched for simply by placing different voltages on deflection plates or running different currents through deflection coils, thus varying the position of the spot on the kinescope. Examination with a magnifying glass or by eye suffices to determine the degree of defocussing.

To test a kinescope and its associated deflection circuits for linearity, a synchronizing generator is required to operate the receiver or monitor holding them and to provide synchronizing signals for the testing instruments. The synchronizing generator is an essential piece of equipment wherever television work is being done, so this is no disadvantage. The synchronizing generator waveforms last recommended by the Radio Manufacturers Association are shown in Figure 9. Of the four outputs, Number 2 (blanking singal) and Number 4 (horizontal driving signal) are required as inputs to the Kinescope Quality Measuring Device which will be discussed at length later on. No. 1 (synchronizing signal) is required to operate the television receiver or synchronized monitor holding the kinescope under test. Numbers 3 and 4 are required instead of Number 1 if the kinescope is in a monitor of the driven type. Frequent reference by name will be made to these waveforms.

2. Horizontal Linearity Bar Generator

To measure sweep linearity, "bar generators" have been used in the past. A bar generator for measuring linearity of the horizontal sweep generates pulses at a frequency which is a multiple of

line frequency. It is synchronized by horizontal drive, or blanking. When the pulses are used as video input for a kinescope, a pattern of vertical bars is produced, since synchronizing causes the pulses occuring on successive horizontal lines to fall exactly beneath those on preceding lines. Because the bar generator is known to be a stable oscillator, the time periods between the vertical lines are exactly equal, and if the horizontal sweep is linear, then the spaces between lines will be equal. Any inequality indicates non-linearity of sweep. Inequality can be most conveniently detected with a piece of flat celluloid marked with equally spaced dots or holes on a straight line along its length. One hole is made to coincide with the left hand vertical line. Using the point marked by this hole as a pivot, the celluloid rule can be rotated until successive holes coincide with successive vertical lines. If it is impossible to obtain coincidence, non-linearity exists. The inequality can then be measured with a scale by locating that hole which is at the greatest distance from an adjacent vertical line, and measuring this distance. The percent non-linearity is then obtained by dividing this distance by the length of one line and multiplying by one hundred.

The schematic of a horizontal linearity bar generator built at RCA Laboratories by D. Pierce appears in Figure 2. Horizontal drive, a negative pulse, is used to synchronize this generator. In V1A, its phase is inverted, so the signal on the grid of V1B is a positive pulse which causes V1B to conduct heavily. V2 is a push-pull oscillator with both cathodes at a potential of plus 125 volts. The two plates have the same plate resistor as V1B, so that when horizontal drive causes V1B to conduct heavily, the plate voltage of V2 drops rapidly to less than 125 volts. V2 then cannot oscillate, since the cathode is at plus 125 volts. As soon as the horizontal drive pulse has passed, V2 starts to oscillate again. This "blanking" type of synchronization eliminates the jitter that often occurs with ordinary synchronization. The push-pull type oscillator was used simply because it was already built and available for use. The sine wave output of V2 is coupled to the grid of V3, which is overdriven. Plate limiting clips the top of the sine wave, and driving the grid below cutoff clips the bottom. The output of V3, therefore, is a square wave, which is differentiated by C1R1. Since V4 is unbiased, the positive portion of the differentiated pulse causes grid conduction and does not appear at V4 plate. The nega-

tive portion is inverted in phase and amplified by V4. The resulting signal on the grid of V5 is a sharp positive pulse. V5 is a cathode follower used to provide low output impedance to match a coaxial line. The frequency of the sharp output pulse can be varied by C2, so that the number of vertical lines is variable.

2. Vertical Linearity Bar Generator.

Figure 3 is the schematic of a vertical linearity bar generator, also built by Pierce. The output of this device, when used as video signal for a kinescope, produces a pattern of equally spaced horizontal lines. The negative vertical drive pulse (Figure 9, Number 3) is inverted and amplified in V1. The resultant positive pulse causes V2A to conduct heavily for the duration of the vertical drive pulse. This current flows through R1, biasing V2B to cutoff. Here again is the "blanking" type of synchronization. V2B is a phase shift oscillator, producing a low frequency output whose frequency is varied by R2 so that it is made some multiple of frame frequency. This type oscillator is used because for the low frequencies involved, the RC network takes up less room than an LC network would. It is also a very stable oscillator. With the switch S1 in the position shown, the sine

wave output is fed to the grid of V4, a cathode follower providing low output impedance for matching a coaxial line. R3 and R4 attenuate the signal so that V4 is not overdriven. With S1 in the position opposite to that shown, the sine wave output of V2 is shaped by V3 into a square pulse having a duration equal to that of one horizontal line. S1 was provided because use of the square pulse sometimes introduced high frequencies and noise into the video circuit of a monitor or receiver and the presentation on the kinescope was not too clear. When this occurred, using the sine wave improved the condition.

These two bar generators are quite satisfactory for determining the linearity of a television picture. On first thought, it might seem that their outputs could be used simultaneously to produce a grid of vertical and horizontal lines so that both horizontal and vertical linearity could be observed simultaneously. Tests, however, fail to bear this idea out. An unstable pattern is produced because of inexact synchronization.

3. British Cathode Ray Tube Quality Measuring Device

In September 1946 issue of "Electronics Engineering" (British)[2], A. N. Spooner, B. Sc., presented an

[2] A.N. Spooner, "Cathode Ray Tube Quality Measuring Apparatus", Electronics Engineering (British), September, 1946.

article and a schematic on a "cathode ray tube quality-measuring device". It made possible the observation of four types of kinescope distortion from the same pattern. This was a marked improvement in convenience over the instruments in use at the RCA television laboratory and just described. Dr. H. N. Kozanowski, supervisor of the advanced and military development section of the laboratory, desired to build and test a device based on Spooner's schematic to see whether or not it would be of practical use to the laboratory. It had been designed for use within the British television system, which differs from the system used in the United States in the following major respects:

Item	U. S.	British
Number of lines per frame	525	405
Number of frames per second	30	25
Transmission polarity (and polarity of synchronizing generator outputs)	Negative	Positive

The tubes used by Spooner were British-made, and types were undesignated. Dr. Kozanowski desired several changes in the presentation given by Spooner's device, and two changes to better adapt it to laboratory use. All these things made necessary a complete redesign, but the circuit types used by Spooner were retained wherever their performance was satisfactory.

A breadboard model was first constructed and tested stage by stage. After seven weeks, the breadboard model worked satisfactorily. Three more weeks were spent in making numerous changes to improve its stability and the clarity of its presentation on a kinescope. Finally, two weeks were spent in building a finished model. This model worked satisfactorily. Had more time been available, a number of improvements could have been made. Hereafter this device will be referred to as the KQMD, an abbreviation for "Kinescope Quality-Measuring Device".

IV - KINESCOPE QUALITY MEASURING DEVICE - THEORY

To investigate the circuit theory of the KQMD, it will be best to start with a consideration of the sort of wave form required to give the desired presentation. Two presentations were found to be desirable:[3]

A. A grid of minute circular dots with the number of dots in a horizontal line variable at will.

B. A grid of horizontal and vertical lines with the number of vertical lines variable.

Let us assume that for both A and B presentations, one <u>hundred and five horizontal elements and five vertical</u>

[3] In Spooner's device, only presentation A was desired, and the output waveform differed in its porportions from the one described here.

elements are desired; this will confine to a reasonable space the demonstration diagrams that follow in Figure 4.

Portions of a wave form which will provide these two presentations when used as a video signal are shown in Figures 4a and 4b. Recall that in odd-line interlaced scanning, one frame produces the complete kinescope pattern and that two fields form a frame. In field number one, the odd lines of the frame are scanned and in field number two the even lines are scanned. Figure 4a represents the beginning of field number one video signal. Each of the wide positive numbered spaces represents a line. The narrow spaces between lines represent horizontal blanking and the very narrow positive pulses are dot pulses. Figure 4b represents the beginning of field number two video signal. Vertical blanking pulses occur just before the starting points of Figures 4a and 4b. Figure 4c shows the top of the corresponding pattern produced on the kinescope if the brightness control of the kinescope is set so that beam current is shut off below the level A. This pattern is presentation A. Figure 4d shows the top of the pattern produced if the brightness control is set so that beam current is shut off below the level B. This pattern is presentation B. The patterns themselves are shown by solid lines, and scanned lines are shown by broken lines.

Elements of the patterns are numbered to correspond to numbered elements of the wave form. Note that in presentation B, the dots aligned vertically are so close together that on the kinescope they will appear as a solid line. By adjusting the brightness and contrast controls of the kinescope, the vertical and horizontal lines can be made approximately equal in tone.

Three wave forms must be generated and combined to provide the composite waveform shown in Figure 4.

a. Flat-topped pulses having a duration very nearly equal to that of one Horizontal line, that is, 63.4 microseconds. The frequency of these pulses must be that submultiple of line frequency which provides a chosen number of visible horizontal lines. We shall refer to these pulses as "pedestals" since they elevate the dot pulses desired as video signal for the grid of dots. Let n equal the number of visible horizontal lines plus the number of horizontal lines that would be visible were they not eliminated by vertical blanking. In order to obtain a stable pattern of motionless horizontal lines, the active lines of all frames must be superimposed. This condition will exist only if the pedestal period is contained within the frame period an integral number of times. Therefore, n must be a factor of the number of horizontal lines per frame, 525. Stated mathematically,

$$n = \frac{525}{2m-1}$$

where m is any integer for which n is a whole number. Substituting all possible values of m, we find that the factors are 1, 3, 5, 7, 15, 21, 25, 35, 75, 105, 175, and 525. The vertical blanking pulse is normally five percent of the field period (see Figure 9) and thus 10% of the frame period. Therefore about 90% of the above numbers will give the numbers of visible horizontal lines per frame that can be obtained. Of the possible values of n, 35 was considered to be a good value for purposes of measuring vertical linearity. The KQMD was designed with that figure in mind. It will provide 32 visible horizontal lines.

b. Very narrow pulses whose frequency is some multiple of line frequency, dependent upon the number of dots per horizontal line desired. It was the consensus of opinion of several RCA engineers that there ought to be four thirds as many vertical lines as horizontal lines in order to observe most easily the quality of linearity. The frequency of dot pulses, then, would be:

$4/3 \times 35 \times 525 \times 30 = 735$ kilocycles per second.

Their period must be constant for linearity purposes. For a stable pattern, they must be synchronized so

that the first dot in each line falls exactly in the same place in successive frames. Since the dots are to be used for observing defocussing, they should be uniform, and truly circular. It would be difficult otherwise, to detect the change in dot shape and size caused by defocussing. Now, if the circular electron beam is not defocussed, it will produce a circular dot when it is intensified by a dot pulse if the duration of that pulse is very short --- on the order of one picture element in length. Since there are only 525 horizontal lines, there can be a maximun of 525 picture elements in the vertical dimension. And since the aspect ratio of the raster is 4/3, there are 4/3x525 elements in a horizontal line having widths equal to their heights. The time duration of such an element would be:

$$T = 1/30 \times 1/525 / 1/525 \times 3/4 = .905 \text{ microseconds.}$$

Thus the dot pulses should be less than .905 microseconds in width.

c. Line and frame blanking pulses. These blank out the retrace of the horizontal and vertical sweeps, which otherwise would mar the kinescope pattern with spurious dots and lines. Line and frame blanking signal is provided by a synchronizing generator and used as one input signal to the KQMD.

The block diagram of Figure 5 indicates how these

three waveforms are generated and combined. Horizontal drive is one input to the KQMD. Its frequency is 15,750 cycles per second. After going through synchronizing pulse shaping circuits, it is used (a) to synchronize the dot pulse multivibrator and (b) to trigger the first divider.

The first divider divides horizontal drive frequency by three and triggers the second divider, which divides by five. The second divider frequency is thus 1/3 x 1/5 x 15750 = 1050 cycles per second. The output waveform is clipped in the pedestal amplifier so that a flat-topped pedestal results. This pedestal wave form provides the thirty-two horizontal line patterns previously discussed.

The multivibrator waveform goes through a shaping circuit, and finally to a dot pulse amplifier.

Composite horizontal and vertical blanking is the other KQMD input. Blanking, pedestal, and dot pulses are combined and sent to a cathode follower whose output impedance matches seventy-five ohm coaxial cable output line.

The schematic of Figure 7 shows all the details of the KQMD circuit.

The following paragraphs will:

a. Explain in detail the operation of the KQMD.

b. Show the necessity for each portion of the circuit.

c. Provide reasons for the selection of the component values used.

d. Point out the weakness of the circuit.

e. Explain the major difficulties and oversights that caused time-consuming delays.

Unless otherwise stated, references to numbered components will be to those appearing in Figure 7. Note that many points on the schematic are lettered. Waveforms taken at some of these points appear in Figure 6 with corresponding letters. They will be frequently referred to in the following discussion. The direct current voltages taken at many of the lettered points are recorded in Figure 8.

V. KQMD CIRCUIT DESCRIPTION

1. General

The circuit of the KQMD can be divided into four major portions.

a. The synchronizing system: V1, V2, and V9.

b. The pedestal generating circuit consisting of tubes V3 and V4.

c. The dot pulse generating circuit, which consists of tubes V9 to V15.

d. The output circuit consisting of a cathode follower, V8, preceded by three tubes which mix three signals: blanking, dot pulses, and pedestals.

Each of these will be discussed in detail, but the discussion will be clarified by first mentioning a few of the facts which affected the design of the KQMD as a whole.

The plate supply voltage of plus 280 volts was selected because that was the output voltage of the portable power supplies in the laboratory and is well within the operating range of the two types of tubes used. The four coupling circuits in the plate voltage supply line were found to be a minimum consistent with stable operation. Without them, feed back through the power supply internal impedance sometimes caused the multivibrator and the dividers to get out of synchronization. 80 microfarad by-pass condensers were used because they were plentiful and that value was sufficiently large to by-pass the frequencies involved. 1000 ohm decoupling resistors were a compromise between adequate decoupling and a reasonable drop in plate voltage. In the interests of ease of replacement and a single filament voltage, it was decided to standarize on 6AC7's for pentodes and 6SN7's for triodes. Both these tubes

have a relatively high figure of merit, N, where

$$N = \frac{g_m}{C_{gk} + C_{pk} + C_{pg}(1+\mu)}$$

This is highly desirable for obtaining reasonable gain at high frequencies, for as frequency increases, the output impedance of a tube decreases because of output capacitance. For triodes,

$$\text{Gain} = \frac{\mu Z_o}{R_p + Z_o}$$

and for pentodes,

$$\text{Gain} = g_m Z_o$$

These formulas indicate that the higher a tube's figure of merit, the greater the gain the tube will provide as frequency increases. The 6SN7 triode also saved considerable space, and this was a factor because the standard chassis available was 10 1/2 inches by 19 1/2 inches. The grid leak resistor values were dictated by the maximum permissible values specified by the tube manufacturer. For the 6AC7, the maximum value that can be used without incurring ion bombardment is .25 megohms, and for the 6SN7, it is one megohm.

Voltage dividers were used rather than dropping resistors for obtaining desired screen voltages for the 6 AC7's because:

a. They provide a better regulated screen voltage.

b. They provide protection where no cathode bias resistor is used should grid signal be lost for some reason.

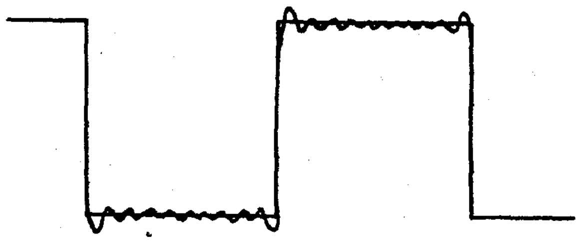
c. They permit easy variation of the value of screen voltage. A variety of values was found necessary.

Where cathode bias resistors are used, various values were tested with the tubes in normal operation, and the one used was that standard value which came closest to providing the bias voltage recommended in the tube manual for Class A operation. Although none of these tubes can be said to be operating strictly Class A, this was a simple means of avoiding overloading and exceeding allowable plate and screen dissipations.

Four considerations controlled the choice of cathode and screen by-pass condensers. First they had to have a value large enough to by-pass all the alternating current components. The smallest value of capacity that would do this was found by use of an oscilloscope and exchanging capacity values. Second, where phase shift of one of the three wave forms with relation to another was involved, it was doubly important to by-pass all alternating current. Third, since the space in which large condensers could be conveniently mounted was limited, physical size was a factor. Fin-

ally, only a few standard values were kept in stock in the laboratory, and it was necessary to select from these.

The wave forms with which the KQMD is concerned are non-sinusoidal, so that frequencies many times higher than the fundamental component must be passed by some of the amplifiers and shapers. For example, below is shown a square wave, and superimposed upon it is shown the wave obtained if the amplitudes of the fundamental and the first twenty-one of its harmonics are added, point by point.[4]



Suppose the frequency of this square wave is 15.75 kilocycles per second. Then the pulse width, S, is 31.8 microseconds. In general, the number of harmonics required to maintain the same quality of reproduction varies inversely with the width of the pulse.[5] Horizontal drive has the frequency of the above square wave, but it is an approximately rectangular pulse having a duration of about 10.7 microseconds, or about

[4] Fink - "Principles of Television Engineering p. 190, McGraw Hill Book Company, Inc.

[5] M. I. T. Staff, "Principles of Radar" pp. 4-12 to 4-17, McGraw Hill Book Company, Inc.

1/3 that of the square wave. To reproduce horizontal drive with the same quality as the square wave, then, requires 3 x 21 = 63 harmonics. This fact determines the character of some of the load or coupling, resistors used. For an RC coupled amplifier, the magnitude of amplification is 70.7% of the mid-frequency amplification at that frequency for which the reactance of Cs, the total shunting capacity in the output, equals the equivalent resistance, Req, where

$$\text{Req} = \frac{1}{\frac{1}{\text{Rc}} + \frac{1}{\text{Rgl}} + \frac{1}{\text{Rp}}}$$

Rc = coupling resistance.

Rgl = grid leak resistance

Rp = Tube plate resistance.[6]

It is clear from the above expression that as Rc becomes smaller, Req become smaller.[7] The smaller Req becomes, the higher the frequency can be before the reactance of a fixed value of Cs equals Req. The smaller Rc is, therefore, the higher is the maximum frequency the circuit will pass unattenuated, and the less it will distort a

[6] F. E. Terman, "Radio Engineers Handbook", page 357, McGraw Hill Book Company, Inc.

[7] This expression for Req is based on the assumption that the coupling capacitance has negligible reactance; but whether it has or not, this statement concerning the value of Rc holds true.

nonsinusoidal waveform.

2. Synchronizing Circuit

The problems encountered in designing the synchronizing circuit, V1, V2, and V9, are typical of development work. A chronological discussion of them will show best why three tubes are required to do what apparently would require one at most.

Horizontal drive signal from a synchronizing generator was chosen as a synchronizing signal. Its amplitude is approximately four volts. An attempt to differentiate it and use the resultant signal to feed both the dot multivibrator and the first divider failed because the amplitude of the differentiated signal was insufficient and there were feedback difficulties. One half of a 6SN7 twin triode was used, therefore, to amplify horizontal drive before differentiation. The dot multivibrator operated at a frequency in the vicinity of 700 kilocycles, and there was enough feedback from it through interelectrode capacitances to the grid of the 6SN7 to interfer with synchronization. A 6AC7 was then used, in place of the 6SN7, to eliminate the plate grid capacitance of the latter. Operation of the dot multivibrator improved, and an oscilloscope test indicated that it was adequately synchronized. Its waveform, though, was slightly distorted during

the synchronizing pulse and for a short time following it because the synchronizing signal was a sharp positive pulse followed about eleven microseconds later by a sharp negative pulse, and this length of time covered several cycles of the multivibrator. The distortion would have interfered with the production of a clear grid of dots equally spaced, so it was necessary to eliminate the negative portion of the synchronizing signals. Two different clipping circuits were tried. A 6H6 twin diode clipper failed to provide adequate isolation between the first divider and the dot multivibrator but triode grid circuit clipping proved satisfactory. The simplest circuit that performed adequately required two 6SN7's and one 6AC7. The input stage was a grounded grid amplifier. Later in the development, the laboratory decided that the input stage should have a high-low input impedance feature. In a development laboratory it often happens that two instruments are using a signal from the same coaxial line and distribution amplifier. The coaxial cable used at the RCA laboratory has a characteristic impedance of 75 ohms. If two instruments, each having an input impedance of 75 ohms are fed from the same coaxial line, that line is terminated in 37.5 ohms and its signal waveform becomes distorted. One instrument should have an input

impedance of 75 ohms and the other should have a very high input impedance in order to terminate the coaxial line properly. For flexibility, then, all laboratory instruments should be designed so that their input impedances can be easily switched between 75 ohms and a high impedance. A grounded grid amplifier cannot have a high input impedance, so the requirement of high-low input impedance made it necessary to revise the circuit once more to the circuit appearing in Figure 7, comprised of V1, V2, and V9. The value of R4 was kept small so as not to distort horizontal drive. The value 3300 ohms gave a positive signal amplitude at c of 3.4 volts, all that was necessary to drive V2, C3 and R6 are a differentiating circuit used to provide a sharp synchronizing pulse for dot pulse and pedestal circuits. (See Figure 6, waveform c.) The negative portion of this wave had to be eliminated to avoid distorting the output waveform of the multivibrator. To eliminate it completely, it was decided to bias V2 beyond cutoff. R9, R7, and C4 provide a direct current voltage at b of 6.3 volts. Since the cutoff voltage of a 6AC7 is in the vicinity of five or six volts, only a portion of the positive part of wave c causes V2 to conduct. The voltage divider R12 and R13 is used to avoid overdriving V9, which must provide a sharp pulse to synchronize the dot pulse

multivibrator. The full output voltage of V2 is used as grid signal for V1B, for the width of the synchronizing pulse for the first divider is not a critical factor as it is for the dot pulse multivibrator, since its period is three times as long as the period of the synchronizing pulse. R12 also isolates the multivibrator from the first divider. A pentode rather than a triode was chosen for V9 to avoid possibility of feedback from the multivibrator to the synchronizing circuit. P1 and P5 were provided to permit variation of the amplitude of the pulses going to the first divider and the dot multivibrator. They would not be necessary in a final model of the KQMD, but were very useful in the development model.

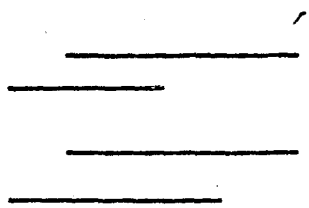
3. Pedestal Circuit

V3 is a plate-coupled multivibrator with a free-running period of a little longer than three times the period of the synchronizing signal, horizontal drive, which is 63.4 microseconds. A positive synchronizing pulse turns V3B on . C10 and R18 are so proportioned that V3B is not switched off until shortly after the second synchronizing pulse passes. C9 and P2 are given values such that the grid of V3B is far below cutoff when the third synchronizing pulse occurs, but close to cutoff when the

fourth synchronizing pulse occurs and turns V3B on, completing the cycle. This cycle, then, is exactly three times the duration of the synchronizing pulse cycle. C11 and R21 differentiate the waveform j, producing the waveform k. The negative portion of the waveform k is used to synchronize the second divider, V4 which is a plate-coupled multivibrator having a free-running period slightly longer than the duration of fifteen horizontal lines. V4B is on for a period slightly less than the length of one horizontal line. C12 and P4 are proportioned so that V4B grid is kept far below cutoff (see waveform m) for the remainder of the cycle, while V4A is on. While grid of V4B is cutoff, one of the negative pulses of waveform k occurs. Since V4A is on at this time, it amplifies the pulse. C12 couples the resulting positive pulse at "n" to the grid of V4B, and V4B is turned on. Before the next positive pulse of k occurs, multivibrator action has cut V4B off and turned V4A on, so that none of the positive pulses of k have any effect on the multivibrator. The next four negative pulses of k have no effect either, because the grid of V4B is so far below cutoff. By the time the sixth negative pulse comes along, V4B is close enough to the cutoff point for the coupled positive synchronizing pulse to turn it on once more, completing the cycle. Thewaveform at

o is a negative rectangular pulse, but its bottom is not square as desired, so it is clipped by driving V5 below cutoff. R26 is purposely left without a by-pass condenser so that degeneration occurs as a means of reducing pedestal amplitude. A number of diode circuits with variable bias were experimented with before the decision to use V5 was reached. The diodes produced pulses no more square than V5 produced and required an additional tube. Appendix 1 contains the calculations made to determine the constants used in the divider circuits.

The greatest difficulty encountered in the pedestal circuit was pick-up from the first divider by the grid of V2. Small positive pulses showed upon the waveform at "c", one for every three normal pulses. They were amplified by V2, V1B and V3, and reached both the multivibrator and the first divider. Their effect on the multivibrator was such as to blur the right hand quarter of the grid of dots, and they caused the first divider to operate out of phase with what should be its normal operation. The effect of the latter was to cause breaks in horizontal lines thus:



Shielding critical leads finally eliminated this difficulty.

4. Dot Circuit

A multivibrator synchronized by differentiated horizontal drive pulses is used to establish dot pulse frequency. Since the frequency of this multivibrator reaches 735 kilocycles per second and more, an expectation of effectively synchronizing it with a 15750 cycle per second signal may seem optimistic. It functions satisfactorily in practice, but adjustments for a stable pattern are critical. The multivibrator is the ordinary plate-coupled type except for the insertion of P6 between the grids and ground. Varying P6 has the effect of slightly changing the grid bias of V10 and V11 so that the point at which they cut off can be shifted. It acts as a vernier for C30, which controls the frequency of the multivibrator and thus the number of dots per line. The necessityfor fine control will be seen if it is recalled that for a stable pattern, the dot pulse frequency must be a multiple of 525, the number of lines per frame. The size of both plate resistors, R50 and R47 is quite small in order that a high frequency of operation can be obtained.

Tubes V12 through V15 shape the multivibrator pulse to the sharp narrow pulse desired for dot pulses.

The wave forms are shown in Figure 6. Note that the screen voltage of V5 was made low, 82 volts, so that cutoff voltage is very small. This shaping circuit is very wasteful of tubes, and requires redesign. No time was available to accomplish this, however, and the circuit as it exists <u>does</u> provide pulses sufficiently sharp to produce fine dots on the kinescope screen.

5. Output Circuit

Tubes V5, V6, and V7 each have a different input signal, but R29 serves as load resistance for all three, so that the waveform q is a composite of the three input signals. This method of mixing is used in preference to a multigrid tube because in such a tube, if any one grid is driven to its cutoff point, the other two have no control, and periods of no signal occur. Such a mixer would also introduce distortion due to nonlinearity. V5 has already been discussed in its relation to the pedestal circuit. V6 provides blanking for the composite signal. Blanking as it comes from the synchronizing generator has a negative polarity, and the same polarity is required in the composite signal. A grounded grid amplifier is employed, therefore, to avoid the use of more than one tube. V7 grid signal is negative dot pulses from

V15. The relative amplitudes of the three component signals in the composite were critical in obtaining the two kinescope presentations desired, and the proper combination was determined by experiment. The desired overall amplitude of the KQMD output signal was between two and three volts to conform to the Radio Manufacturers Association design specifications for video amplifiers. The overall amplitude and the relative amplitudes desired were obtained by juggling R26, R32, and screen bias voltages.

One of the most interesting difficulties encountered in building the KQMD occurred in the output circuit. A small portion of the top left-hand corner of the pedestal in waveform q disappeared at intervals. The intermittent action indicated that a parasitic was causing the difficulty. R33 was not a part of the circuit at that time, and inserting it eliminated the distortion. V8, the cathode follower, provides an output impedance of 75 ohms to match coaxial lines.

VI OPERATION

The output of the KQMD is used as video input to a television receiver or monitor holding the kinescope under test. The contrast control of the receiver or monitor should be set at maximum, and the brightness control adjusted to eliminate blooming. It takes about

five minutes for the KQMD to warm up and provide a stable pattern on the kinescope. If at the end of that time a stable pattern has not been produced, adjusting C30 and P6 slightly will stablize the pattern vertically, and provide the desired number of vertical elements for the pattern. Readjusting P2 slightly will usually stablize the pattern horizontally. If it does not, it is best to follow the procedure below:

1. Use horizontal drive as an external synchronizing pulse for an oscilloscope. Adjust the synchronizing gain and do not change it during the remainder of this procedure. With horizontal drive as signal on the vertical plates, set the oscilloscope sweep so that fifteen pulses are visible on the sweep trace. Do not change the sweep setting thereafter.

2. Put the vertical plate lead of the oscilloscope on point h, i, or j and adjust P2 so that five complete cycles appear on the oscilloscope trace.

3. Put the vertical plate lead of the oscilloscope on point m, n, or o, and adjust P4 so that one complete cycle is visible on the oscilloscope trace. The kinescope pattern will now be stablized horizontally.

If small portions of lines are visible at either end of the horizontal lines and adjacent to them, adjust

adjust P3 to eliminate them. P3 changes the pedestal width.

Turning the brightness control of the receiver or monitor down will provide the grid of dots on the kinescope. Turning it up will provide the grid of lines. Some readjustment of the contrast control may be desirable.

When using the grid of lines, vertical lines only can be obtained by opening switch S1, which turns off the pedestal circuit. Horizontal lines only can be obtained by opening Switch S3, which turns off the dot circuit. Linearity can be measured as described for the bar generators.

The grid of dots can be used for observing linearity as well as the grid of lines, but RCA engineers preferred lines for this purpose, and that is the reason for providing two presentations. Its primary use, however is for observing defocussing. By using a magnifying glass, changes in the size and shape of dots in various parts of the raster can be observed.

The shape of either the line or dot presentation will disclose barrel and pincushion distortion, if they are present.

APPENDIX

Calculation of Circuit Elements for Dividers in the Pedestal Circuit

1. General.

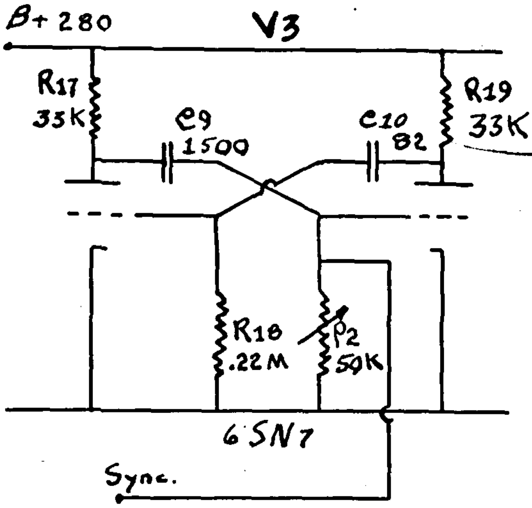
a. With grid voltage equal to 0, a 33000 ohm load resistor, and 280 volts B plus voltage, the voltage at the plate of a 1/2 6SN7 tube is about 70 volts, and plate resistance is approximately 9000 ohms.

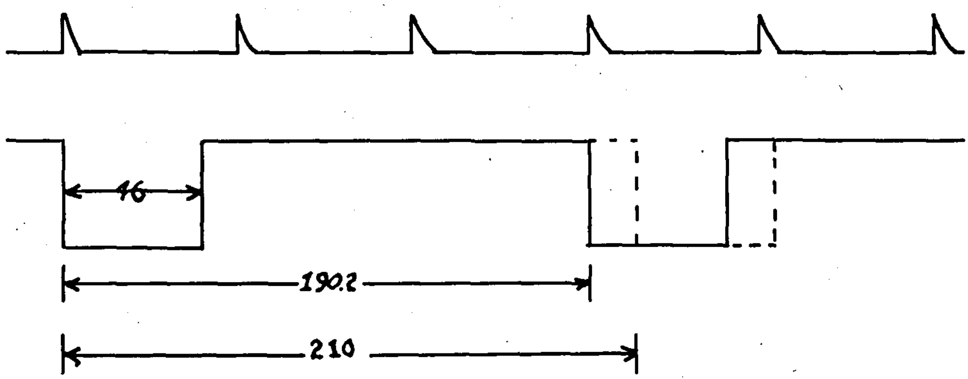
b. Cutoff voltage for a 1/2 6SN7 having B plus voltage of 280 volts is approximately 16 volts.

c. The "off" period of a tube in a multivibrator is determined by the length of time required to have its grid reach cutoff after the condenser coupling the grid to the plate of the other tube commences discharging through its grid resistance.

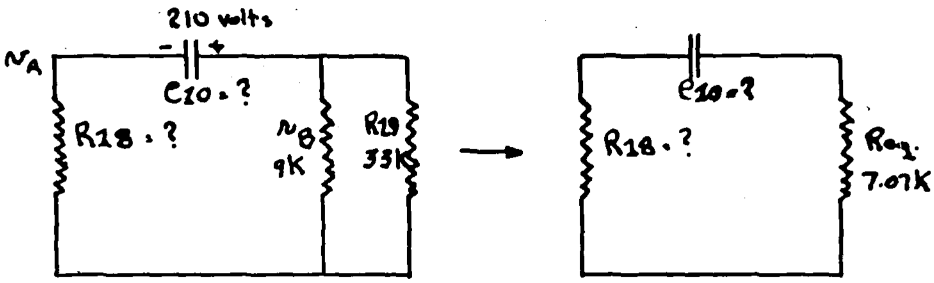
2 First Divider

Circuit :





Approximate desired waveform for Plate V3 B showing its relation to synchronizing pulses. The dotted line shows the divider's free-running cycle. The solid line shows its synchronized cycle.



Equivalent discharge circuit for C_{10}

$V_A = 16 = 210\ \varepsilon^{-\frac{t}{RC}}$

$\varepsilon^{-\frac{t}{RC}} = \frac{16}{210} = .076$

$\frac{t}{RC} = 2.58$

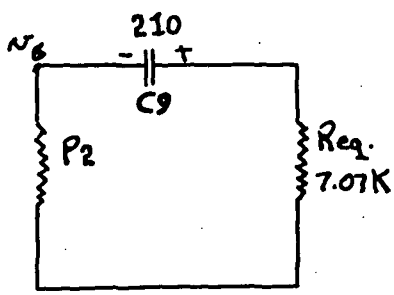
$t = 46\,(10)^{-6}$

$RC = \frac{46\,(10)^{-6}}{2.58} = 18\,(10)^{-6}$

Let $C = 82\ \mu\mu f = C_{10}$

Then $R = 220\text{ K} = R_{18}$

Equivalent discharge circuit for C_9 :



$V_B = 16 = 210\ \varepsilon^{-\frac{t}{RC}}$

$t = 154\,(10)^{-6}$

$RC = \frac{154\,(10)^{-6}}{2.58} = 59.7\,(10)^{-6}$

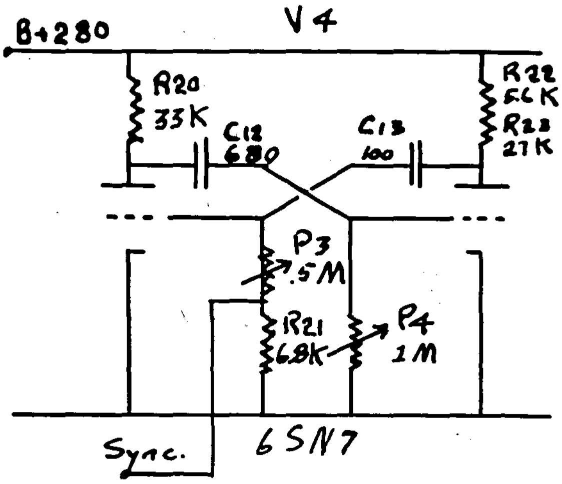
Let $C = 1500\ \mu\mu f = C_9$

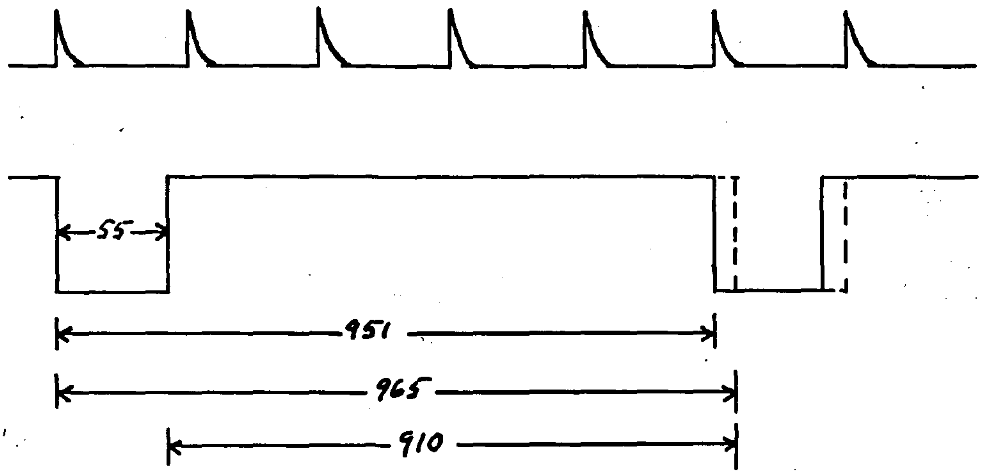
Then $R = 39.8\text{ K}$

Therefore make P_2 a 50 K potentiometer

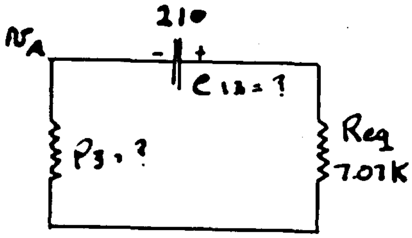
3. Second Divider

Circuit:





Approximate desired waveform for Plate V4B showing its relation to synchronizing pulses. Dotted line shows free-running cycle. Solid line shows the synchronized cycle. The 55 μsecond pulse is used for pedestal width because it is the length of one line, H, less .15 H for blanking.



Equivalent discharg circuit
for C_{13}:

$v_A = 16 = 210\,\varepsilon^{-\frac{t}{RC}}$ $\therefore t/RC = 2.58$

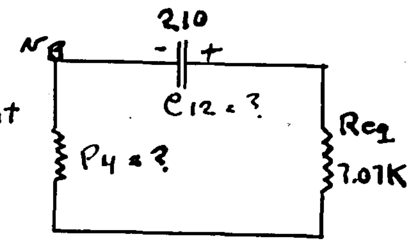
$t = 55\,(10)^{-6} = 2.58\,RC$

$RC = 21.3\,(10)^{-6}$

Let $C = 100\,\mu\mu f \equiv C_{13}$

Then $R_A = .213\,(10)^6$

$\therefore$ Make P_3 = .5 Megohm.



Equivalent discharge circuit
for C_{12}:

$v_B = 16 = 210\,\varepsilon^{-\frac{t}{RC}}$ $\therefore \frac{t}{RC} = 2.58$

$t = 910\,(10)^{-6}$

$RC = \frac{910\,(10)^{-6}}{2.58} = 352\,(10)^{-6}$

Let $C = 680\,\mu\mu f \equiv e_{12}$

Then $R = .518\,(10)^6$

Therefore, let P_4 = 1 Megohm.

To measure the widths of pulses actually obtained for comparision with the computed values, an interesting instrument called the Rise Time Measuring Device was available at the RCA laboratory. It was designed by Howard Morrison of RCA, and a report on it is to be published in a technical journal at an early date. It is a convenient means of determining the length of time between two points of a wave form of television frequency. One output of the Rise Time Measuring Device is a sine wave sweep of a single frequency, 15750 kilocycles per second. The oscillator producing this sweep is synchronized by an external source that produces 15750 cycle per second negative pulse, horizontal drive, for example. A second output is a very sharp negative pulse of about .2 microseconds width, having the same frequency as the sine wave sweep. This is used to blank the beam of an oscilloscope cathode ray tube, thus producing a small well-defined black dot on the sweep. A compensated goniometer provides for shifting the phase of the dot from 0 degrees to 360 degrees, from one end of the sweep to the other. The difference between two goniometer scale readings can easily be converted to microseconds. Thus by moving the small black dot from one point of a waveform to another, the length of time in microseconds between these two points can be measured.

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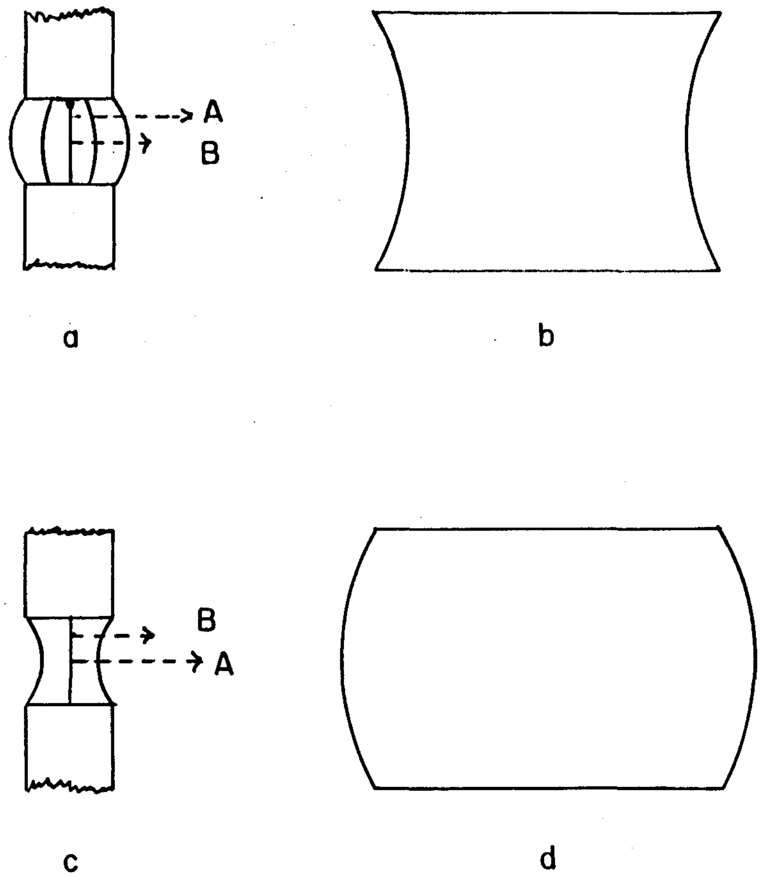


Notes:

1. Dotted lines indicate movement of electrons.
2. Density of magnetic flux is greater in regions. A than in regions B.

Figure 1

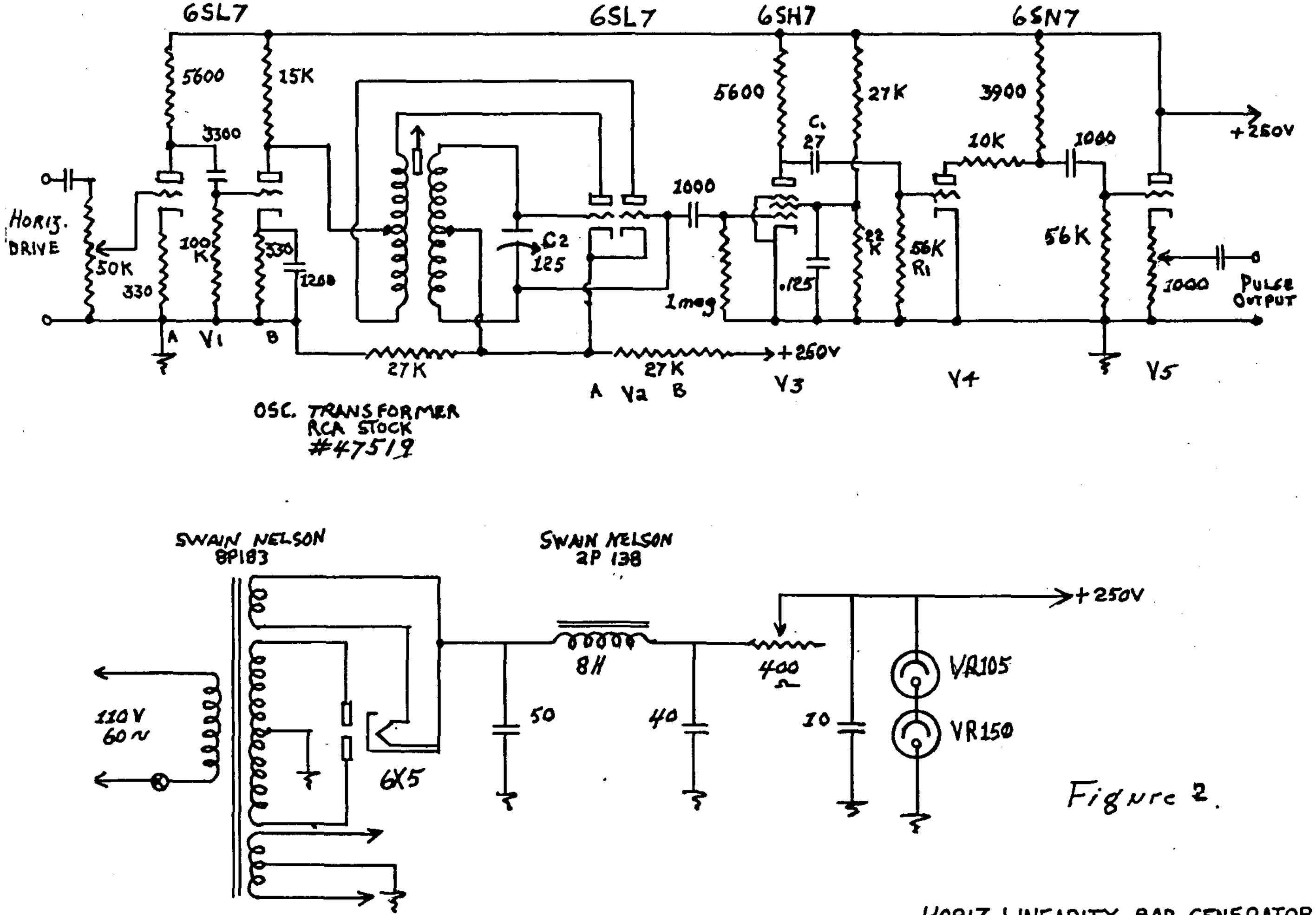


Figure 2.

HORIZ. LINEARITY BAR GENERATOR

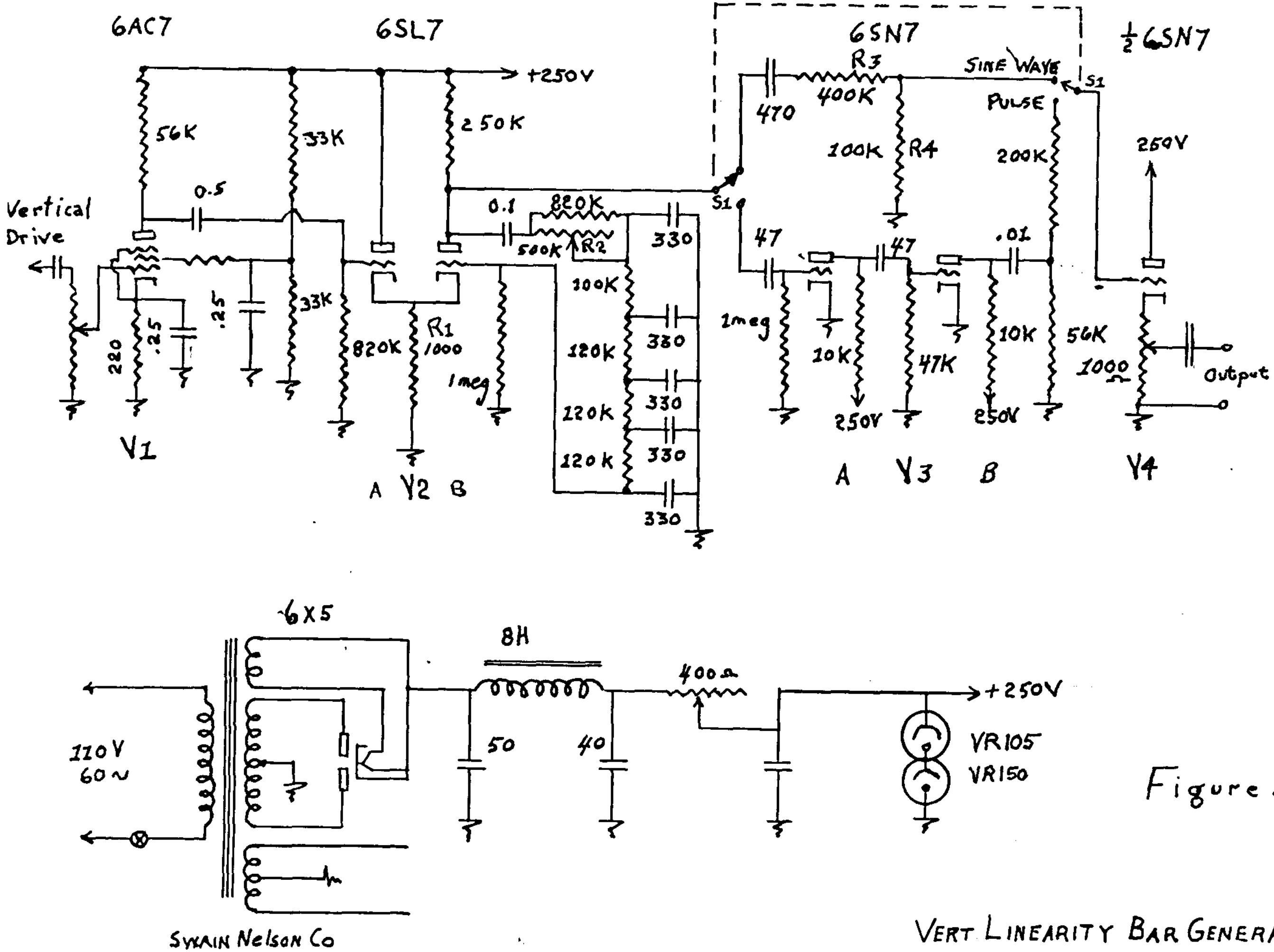


Figure 3

VERT LINEARITY BAR GENERATOR

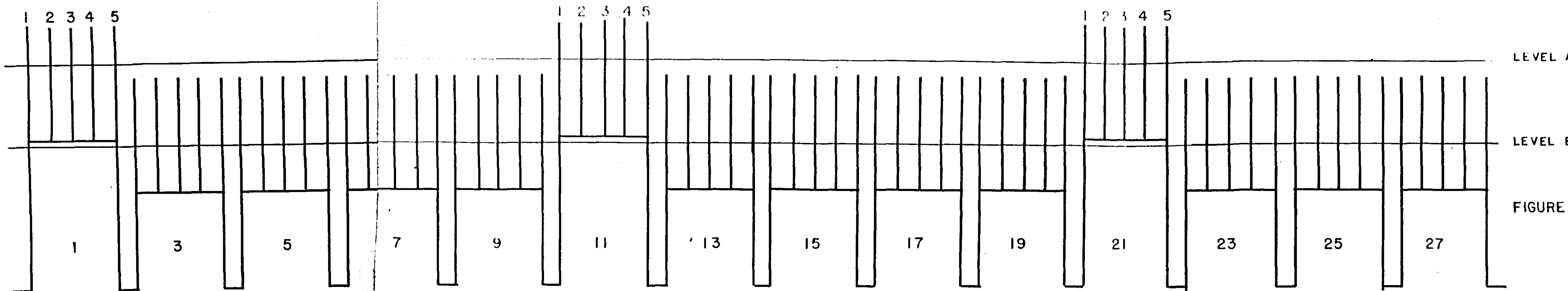


FIGURE 4a

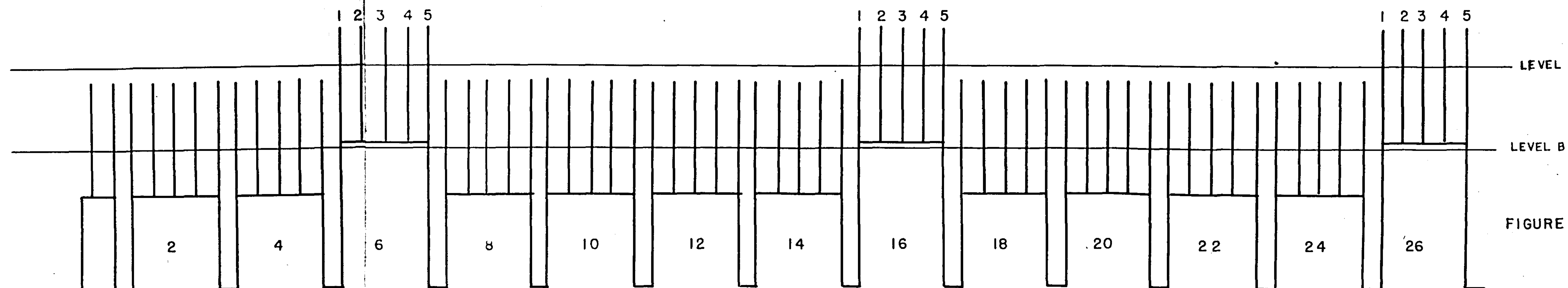


FIGURE 4b

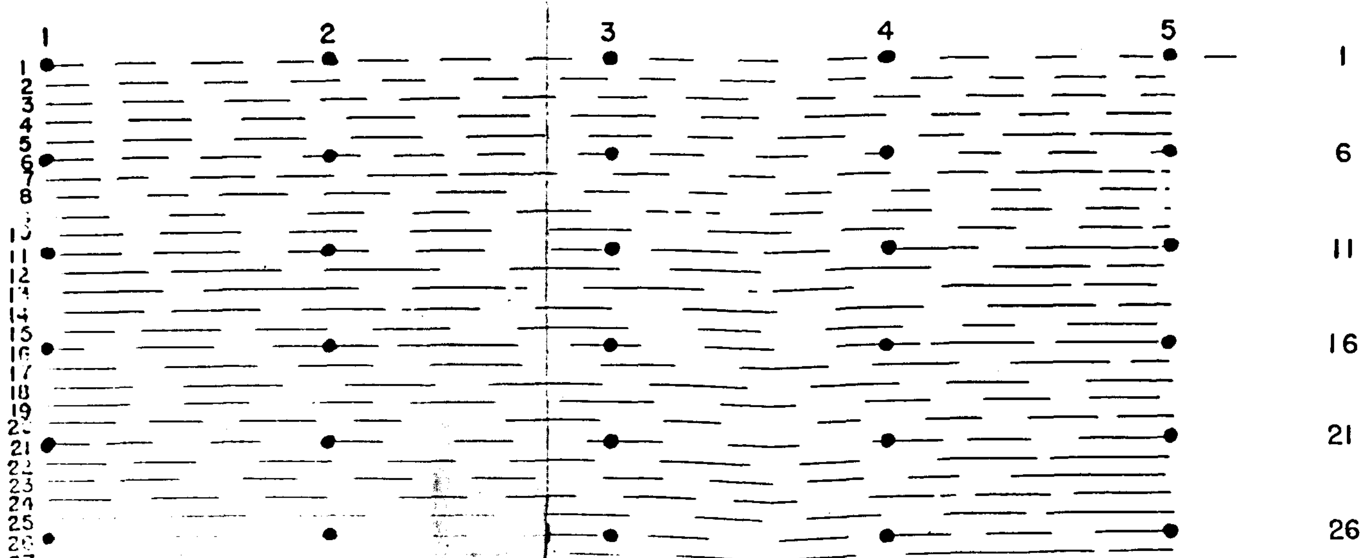


FIGURE 4c

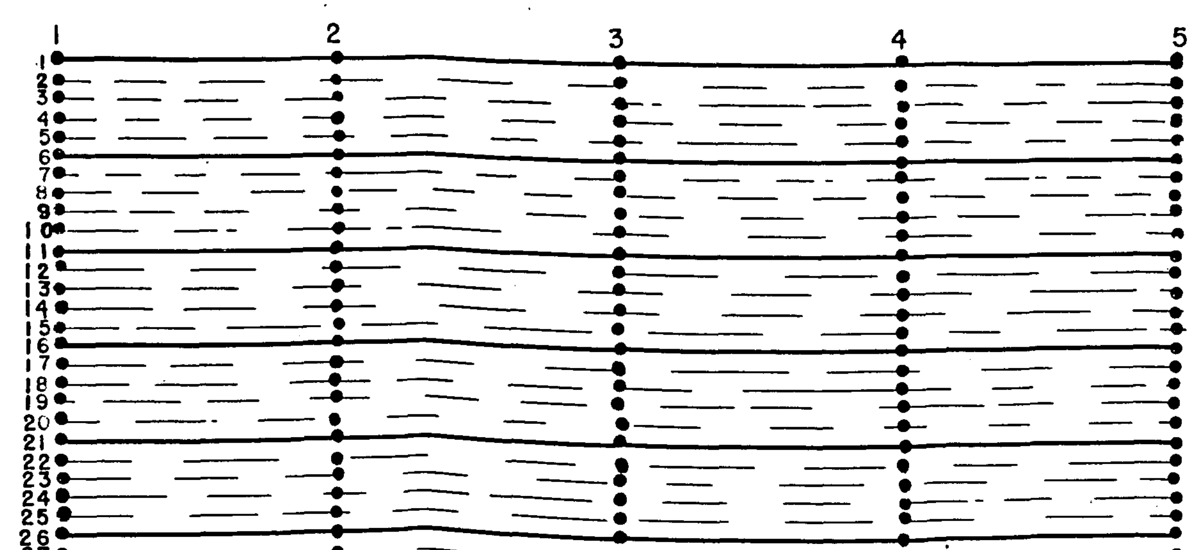
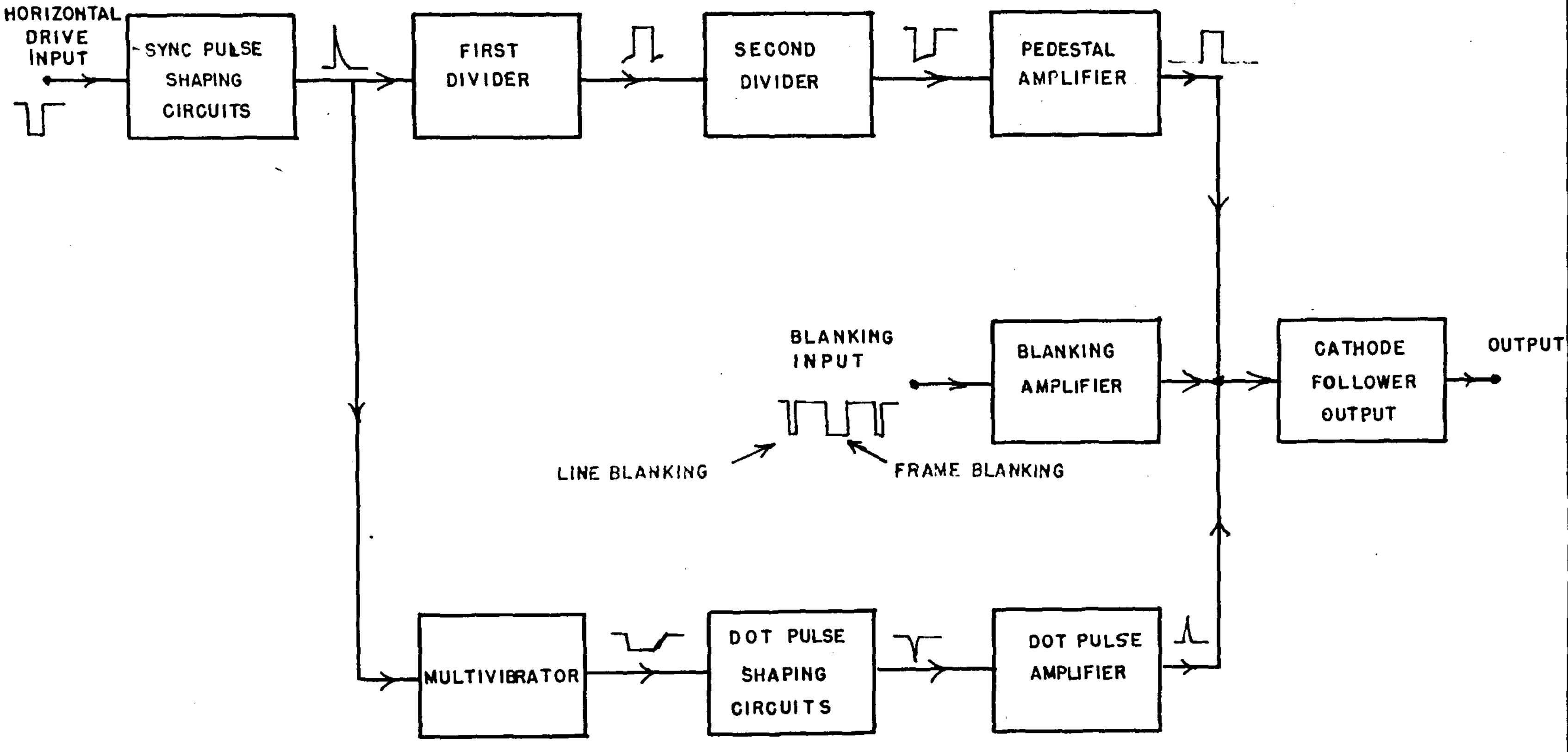


FIGURE 4d



BLOCK DIAGRAM - KINESCOPE QUALITY MEASURING DEVICE

Figure 5

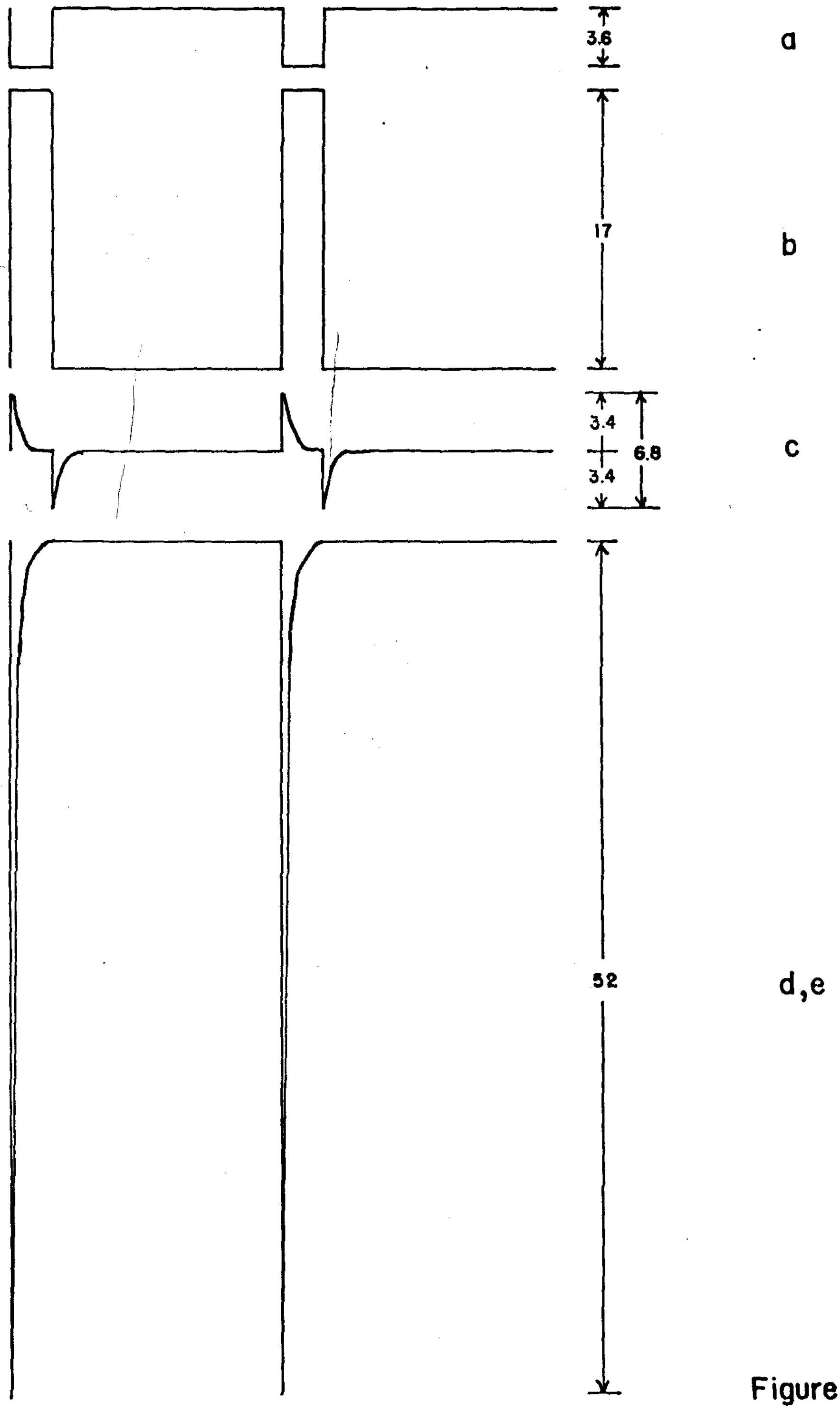


Figure 6

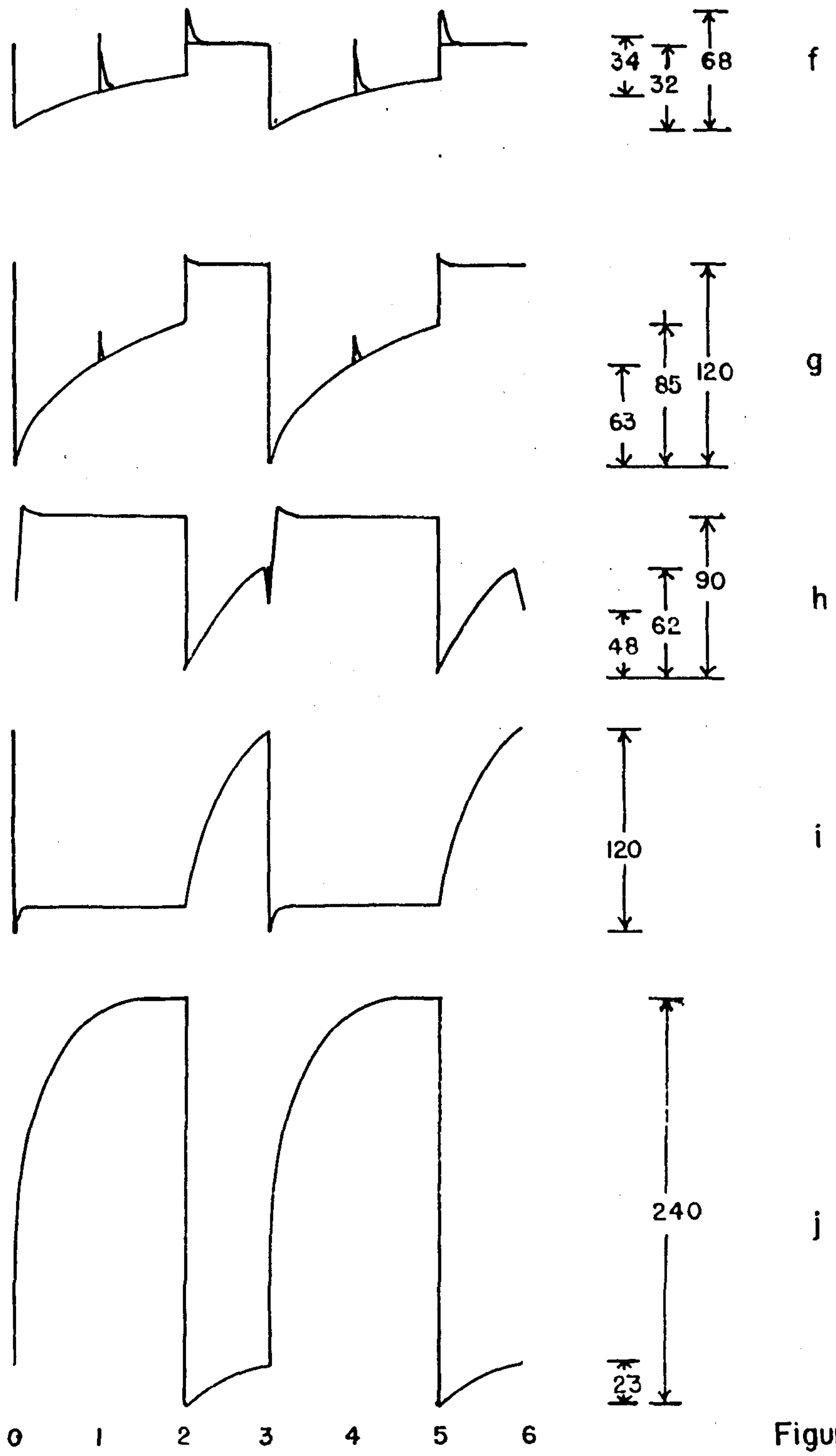


Figure 6

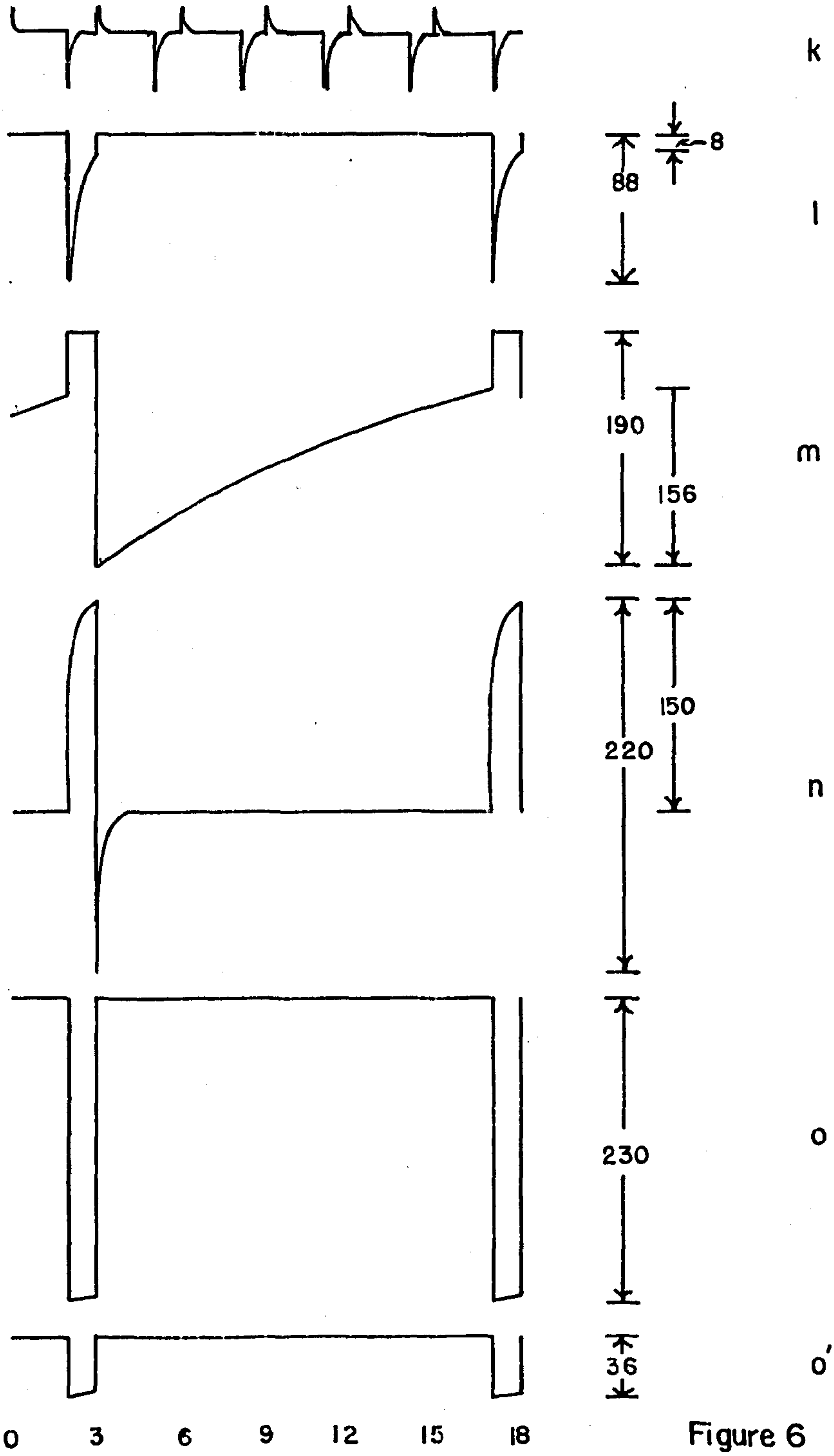


Figure 6

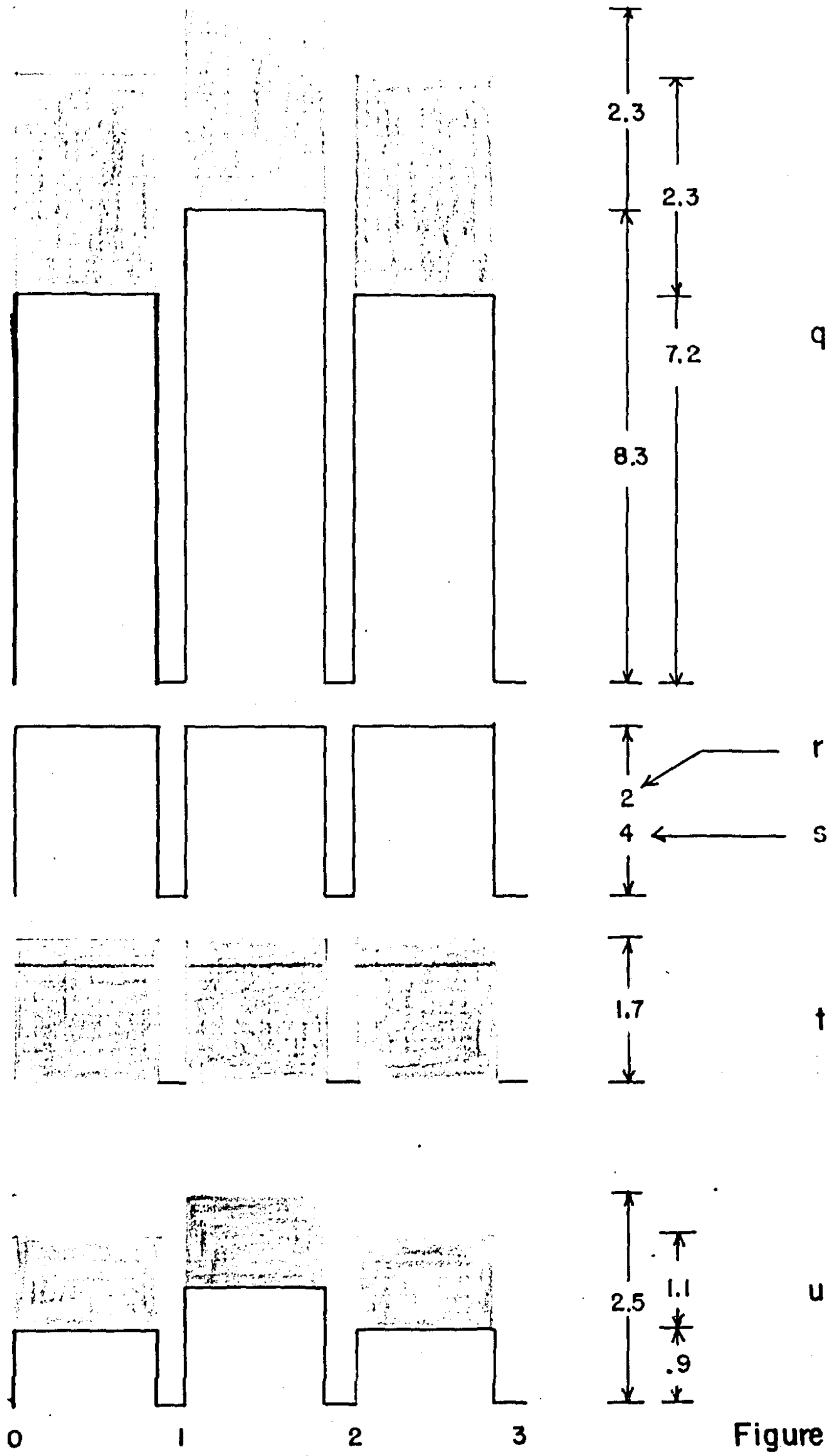
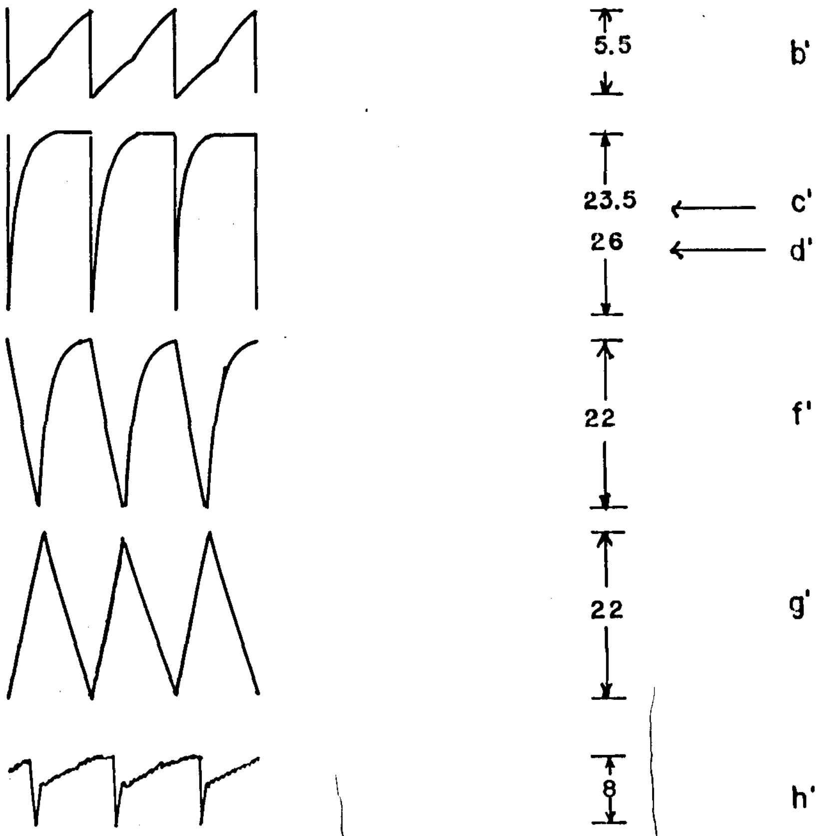


Figure 6

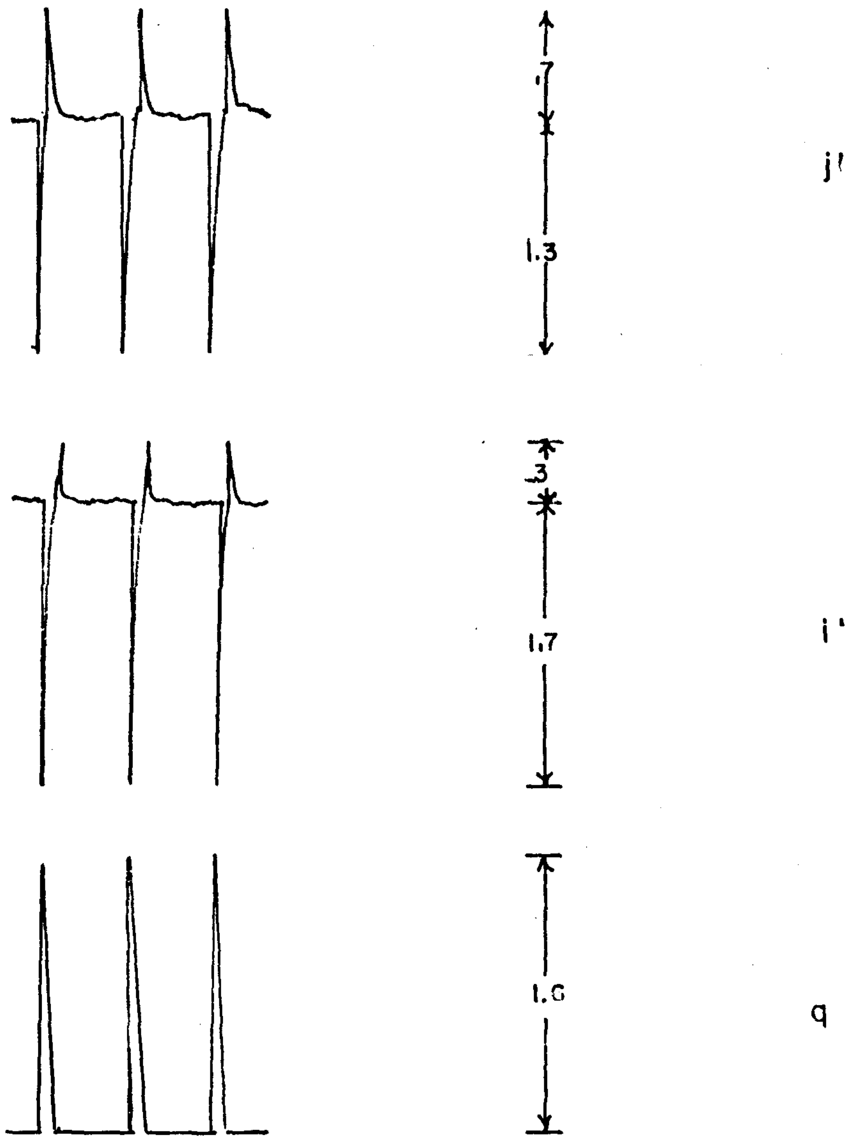


Notes.

1. A variable number of the above cycles, from about 20 to 60 occur in one period, H.

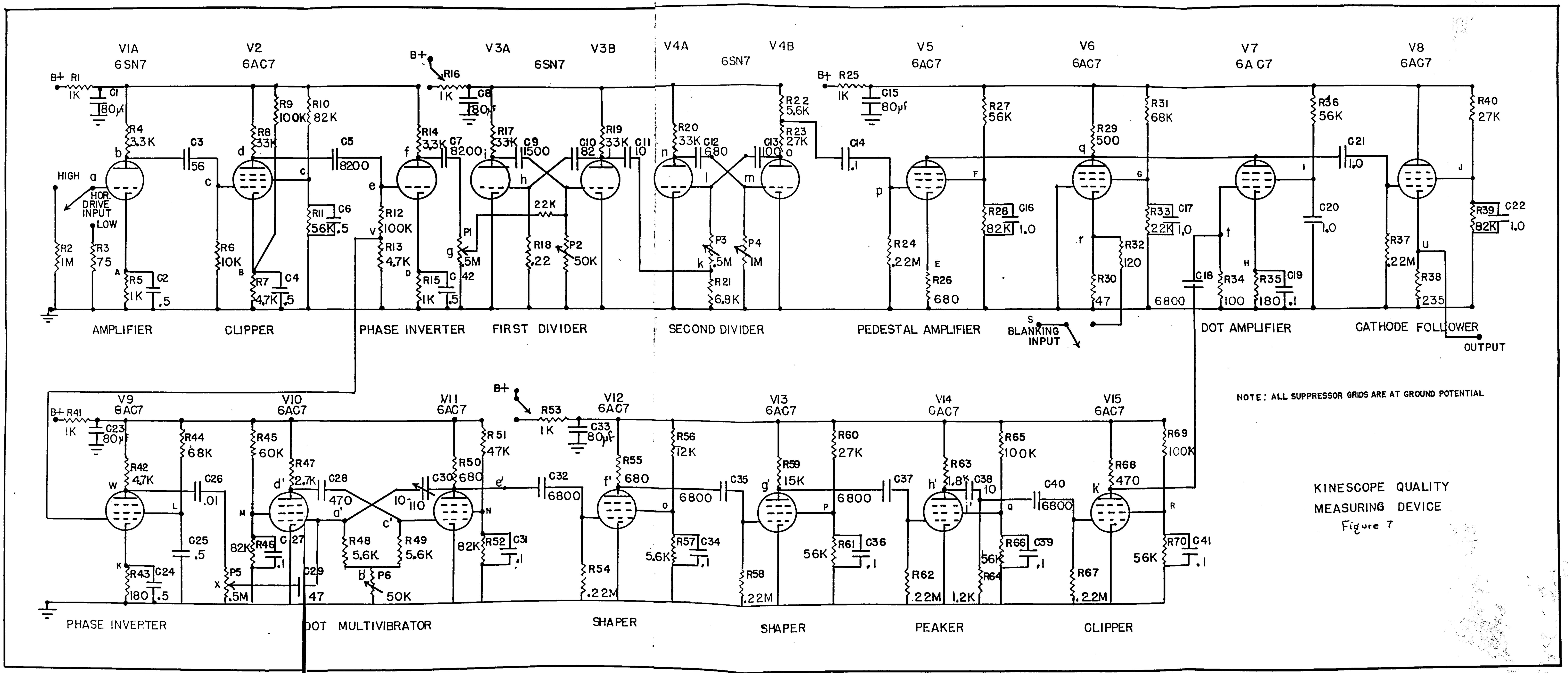
2. Wave forms at points a' and e' could not be obtained because oscilloscope input capacitance upset multivibrator circuit.

Figure 6.



Note: For q, blanking and pedestal circuits were not functioning.

Figure 6



KINESCOPE QUALITY MEASURING DEVICE

Figure 7

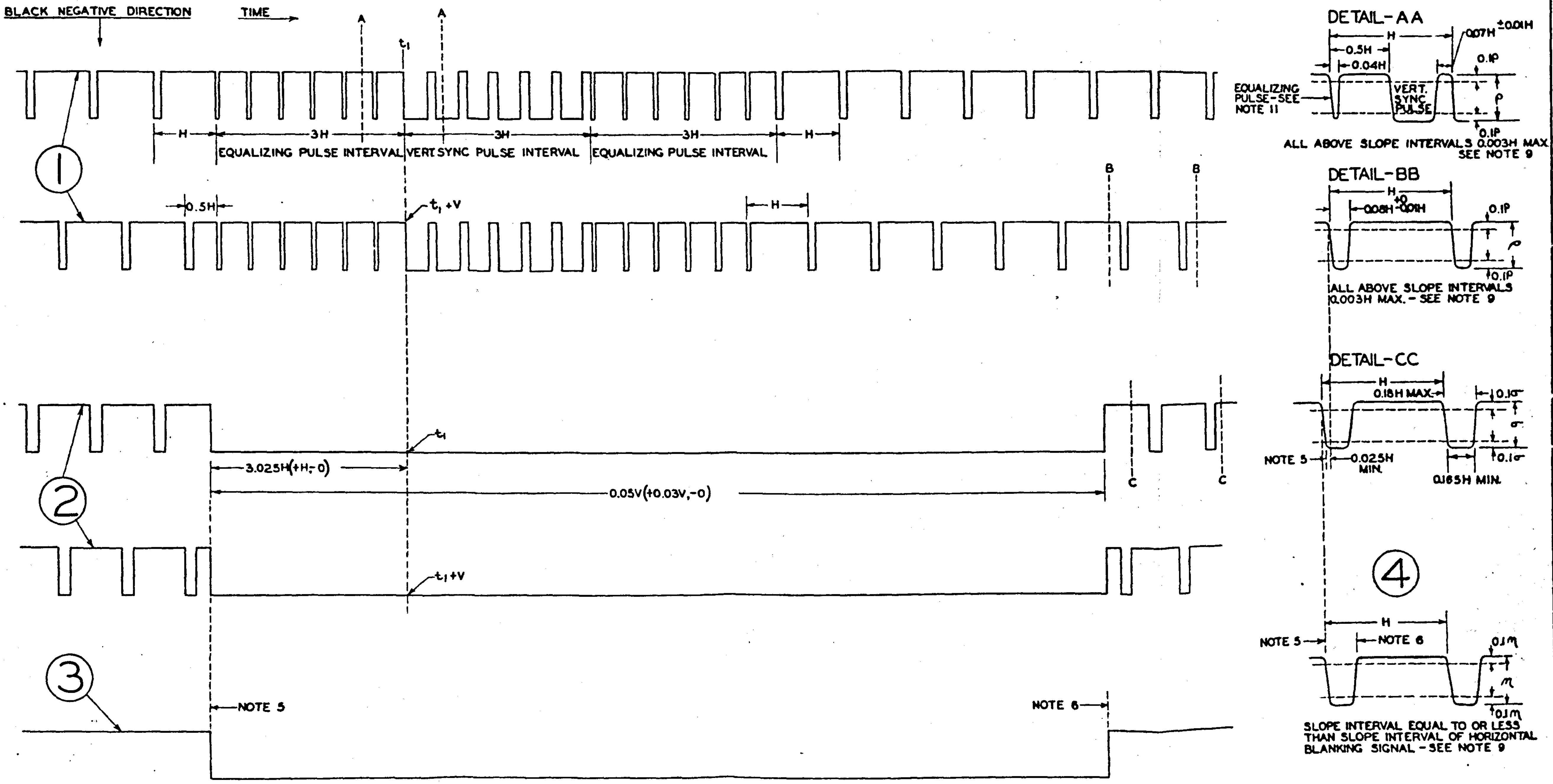
Point	DC Voltage	Point	DC Voltage	Point	DC Voltage
a	0	a'	-3.9	P	95
b	242	b'	-3.7	Q	80
c	0	c'	-5.3	R	82
d	257	d'	209		
e	9.2	e'	244		
f	217	f'	246		
g	-24.3	g'	240		
h	-40	h'	242		
i	109	i'	246		
j	165	A	7.6		
k	-.17	B	6.3		
l	-5.5	C	107		
m	-61.0	D	9.1		
n	98	E	3.7		
O	255	F	120		
o'	267	G	50		
p	0	H	1.6		
q	238	I	144		
r	.20	J	137		
s	.16	K	1.52		
t	0	L	156		
u	.82	M	118		
v	0	N	83		
w	-3.9	O	177		

FIGURE 8.

RECOMMENDED SYNCHRONIZING GENERATOR WAVEFORMS

1- SYNCHRONIZING SIGNAL 2- BLANKING SIGNAL 3-VERTICAL DRIVING SIGNAL 4- HORIZONTAL DRIVING SIGNAL

ALL SIGNAL AMPLITUDES TO BE MORE THAN 3.5 VOLTS AND LESS THAN 8.0 VOLTS ACROSS 75 OHMS. BOTH SIGNAL POLARITIES SHALL BE AVAILABLE. POSITIVE POLARITY NOT SHOWN AND PULSE WIDTHS NOT TO SCALE.



NOTE:-

1- H = TIME FROM START OF ONE LINE TO START OF NEXT LINE.
2- V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD.
3- LEADING AND TRAILING EDGES OF VERTICAL DRIVING AND VERTICAL BLANKING SIGNALS SHOULD BE COMPLETE IN LESS THAN 0.1H.
4- ALL TOLERANCES AND LIMITS SHOWN IN THIS DRAWING APPLY FOR LONG TIME VARIATIONS ONLY AND NOT FOR SUCCESSIVE CYCLES.
5- TIMING ADJUSTMENT, IF ANY, MUST INCLUDE THIS CONDITION.
6- HORIZONTAL AND VERTICAL DRIVING PULSE WIDTHS ARE ADJUSTABLE FROM ONE HALF TO ONE TIMES THEIR RESPECTIVE BLANKING PULSE WIDTHS.
7- THE TIME RELATIONSHIP AND WAVEFORM OF THE BLANKING AND SYNCHRONIZING SIGNALS SHALL BE SUCH THAT THEIR ADDITION WILL RESULT IN A STANDARD RMA SIGNAL. THE TIME RELATIONSHIP MAY BE ADJUSTABLE BUT MUST INCLUDE THIS CONDITION.
8- THE STANDARD RMA VALUES OF FREQUENCY AND RATE OF CHANGE OF FREQUENCY FOR THE HORIZONTAL COMPONENTS OF THE SYNCHRONIZING SIGNAL AT THE OUTPUT OF THE PICTURE LINE AMPLIFIER SHALL ALSO APPLY TO THE HORIZONTAL COMPONENTS OF THE OUTPUT SIGNALS FROM THE RECOMMENDED SYNCHRONIZING GENERATOR.
9- ALL SLOPE INTERVALS TO BE MEASURED BETWEEN 0.1 AND 0.9 AMPLITUDE REFERENCE LINES.
10- THE TIME OF OCCURRENCE OF THE LEADING EDGE OF ANY HORIZONTAL PULSE "N" OF ANY GROUP OF TWENTY HORIZONTAL PULSES APPEARING ON ANY OF THE OUTPUT SIGNALS FROM A RECOMMENDED SYNCHRONIZING GENERATOR SHALL NOT DIFFER FROM "NH" BY MORE THAN 0.0008H WHERE H IS THE AVERAGE INTERVAL BETWEEN THE LEADING EDGES OF THE PULSES AS DETERMINED BY AN AVERAGING PROCESS CARRIED OUT OVER A PERIOD OF NOT LESS THAN 20 NOR MORE THAN 100 LINES.
11- EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF THE AREA OF A HORIZONTAL SYNC. PULSE.
12- THE OVERSHOOT ON ANY OF THE PULSES MUST NOT EXCEED 2%

RMA SUBCOMMITTEE ON STUDIO FACILITIES
APPROVED JAN 22 1946

Figure 9

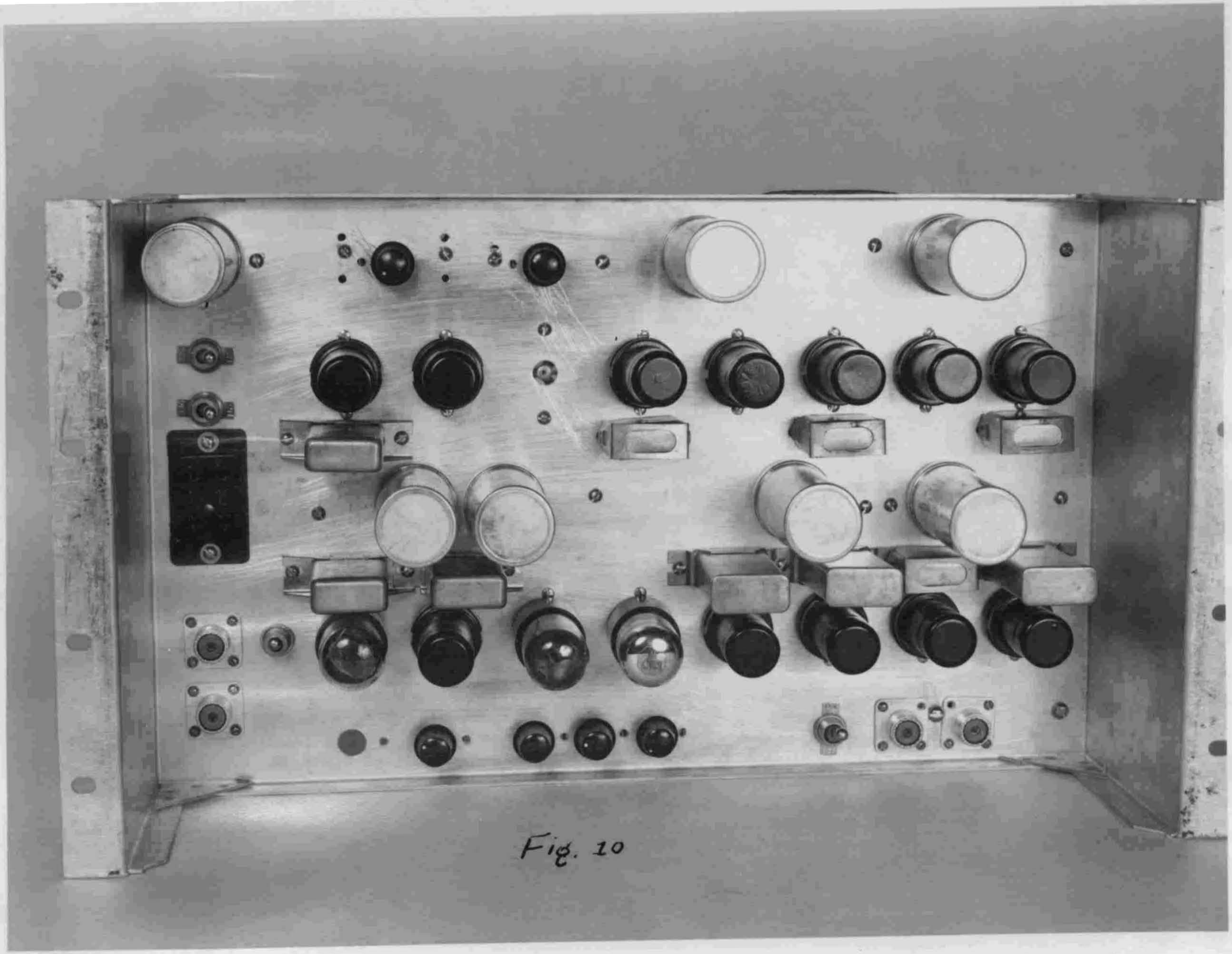


Fig. 10

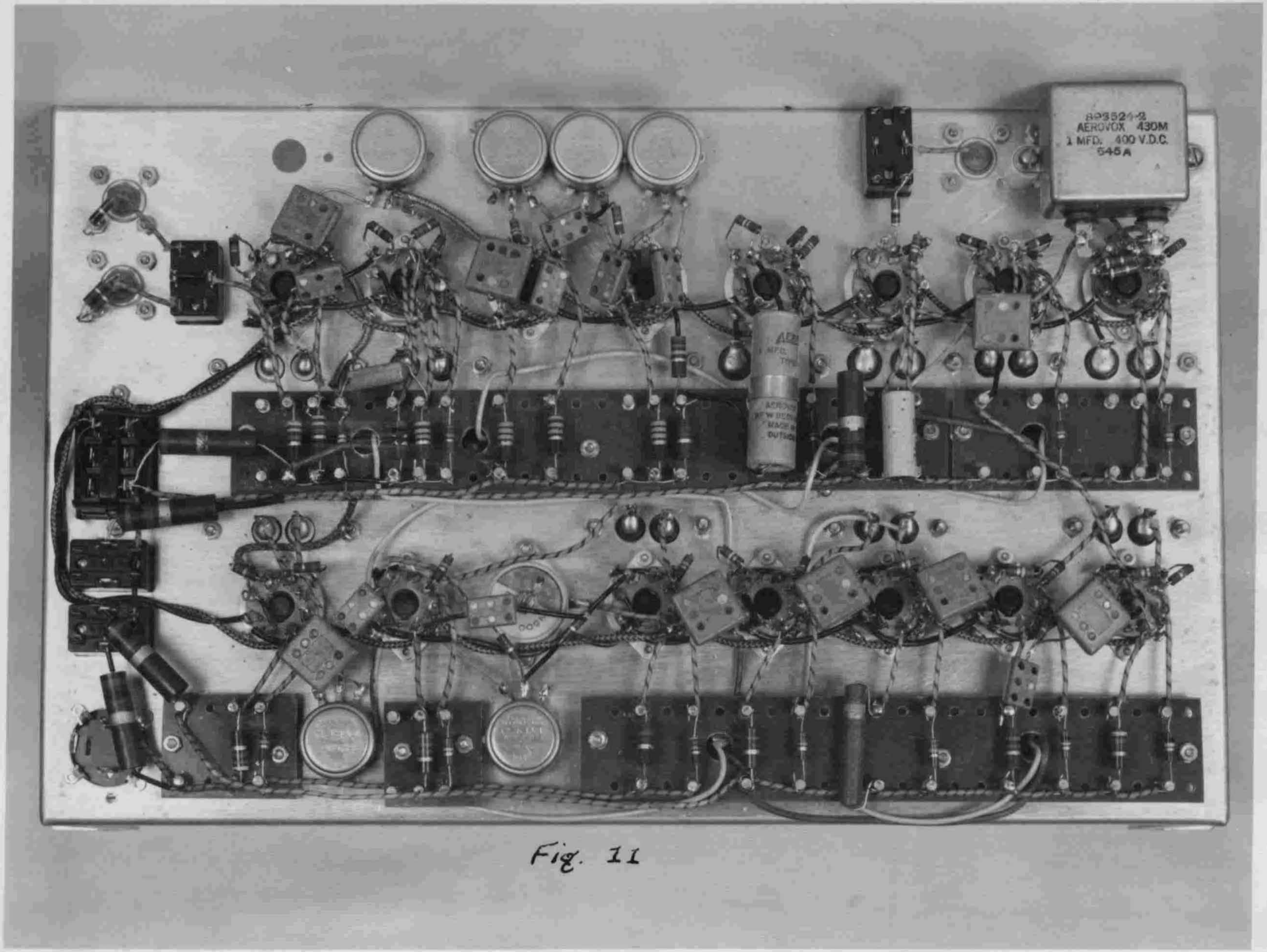


Fig. 11